ASSESSMENT OF THE FLOODS POTENTIAL IN JIU RIVER CATCHMENT

TELTEU CAMELIA ELIZA[1], BRĂNESCU EMILIA, BERGHEZAN AURELIA

ABSTRACT. Assessment of the floods potential in Jiu River Catchment. The floods are extreme hydrological events that require rigorous analysis to achieve structural and non – structural measures to mitigate their risk. This paper aims to analyze the floods' potential in the Jiu River Catchment (the catchment area has 10131 km²). The main geographical factors which are favoring the floods production are the climatic conditions and the morphometric factors. The monthly and annual maximum discharge recorded at 18 hydrometric stations, have been analyzed for the interval 1982 – 2012. In this paper the frequency of the annual floods was determined and the features of 180 floods have been estimated. The used methods are statistical analysis and spatial analysis using GIS. The peak discharges recorded at the studied hydrometric station ranged from 34.2 m³/s to 1220 m³/s. These exceeded the estimated values of the maximum discharge with the probabilities of 1% (Broşteni, Teleşti and Corcova hydrometric stations), 3% (Sadu, Runcu, Stolojani, Târmigani, Strehaia and Breasta hydrometric stations), 5% (Iscroni, Rovinari, Podari, Zăval, Turburea and Turceni hydrometric stations) and 10% (Filiaşi, Răcari and Celei hydrometric stations). The annual floods occurred predominantly in the spring and are the result of the abundant rainfall associated with snowmelt.

Keywords: Jiu River Catchment, monthly and annual discharge, floods, frequency, statistics.

1. INTRODUCTION

The floods are natural phenomena "relatively concentrated and intense, fast – moving, sometimes downright brutal and devastating" (Diaconu and Şerban, 1994, page 78). Their genesis may be due to the snowmelt, rainfall or both.

In the Jiu River Catchment, the floods due to the rainfall cause the highest peak flows and the floods due to the snowmelt or which have mixed origin cause the largest volumes of water (Mustaţă, 1966).

Among recent events, the 2013 spring stands out by some large – scale floods that determined the exceeding of the alert thresholds at 20 hydrometric stations, the threshold danger at Filiaşi HS (460+3 cm) and Răcari HS (485+27 cm), and the flooding of 3634 ha infield, 46 household annexes, 208 ha with forest and 332 ha with grassland (Comitetul Judeţean pentru Situaţii de Urgenţă – Dolj, 2013). The main causes of these floods were heavy rainfall (the values of 24 – hour

[1] National Institute of Hydrology and Water Management, Bucharest, Romania
e-mail: elizapascu25@gmail.com

accumulated precipitation ranged between 20 and 63 mm), the high air temperatures and the snowmelt.

The purpose of this study is to analyze the floods potential in the Jiu River Catchment.

The Jiu River Catchment has an area of 10131 km² and an average drainage density of 0.41 km km⁻². The Jiu River has a length of 325 km and drains the western part of the Carpathians Mountains, the Mehedinţi Plateau, the Getic Subcarpathians, the western part of the Getic Plateau and the Oltenia Plain (the values mentioned above have been obtained using GIS techniques). The lengths of the analyzed rivers vary between 12.6 km (Orlea River) and 323 km (Jiu River, at Zăval HS). The catchment areas vary between 62 km² (Orlea River) and 10073 km² (Jiu River, at Zăval HS) and the average altitudes range between 201 m (Raznic River) and 1134 m (Jiul de Vest River) (Table 1) (National Institute of Hydrology and Water Management, 2013).

This study relies, on the one hand, on the analysis of the main factors which determine the flood production and on the other hand, on the analysis of the spatial and temporal variability of the maximum flow, the frequency of annual floods, the flood's features.

2. DATABASE AND METHODOLOGY

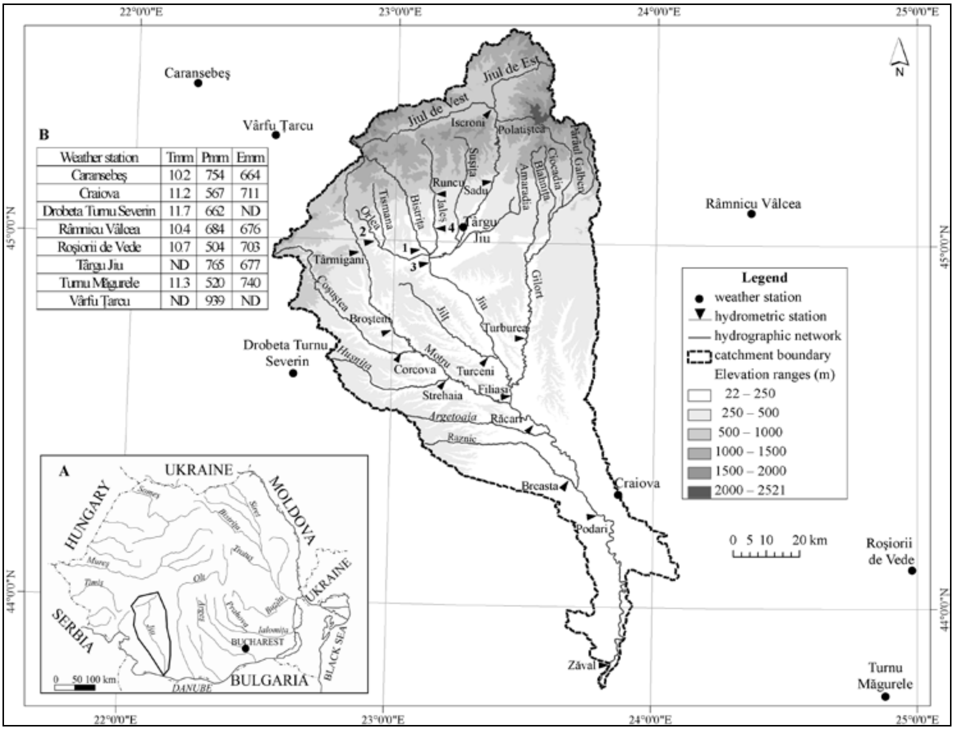
The database includes the hydrological data recorded at 18 hydrometric stations (HS), as: the maximum annual discharge, the maximum monthly discharge, the daily and hourly discharge during the analyzed floods. The data belongs to the National Institute of Hydrology and Water Management (NIHWM), for the interval 1982 – 2012. The maximum annual discharge was used to estimate the maximum discharge with the exceeding probability of 0.1%, 1%, 3%, 5% and 10%, using the ASIG software created in the NIHWM. To identify the trends in the variability of the maximum annual discharge, we used the nonparametric statistical test Mann – Kendall (using MAKESENS 1.0. software, made by the Finnish Meteorological Institute – (Chirilă/Neculau, 2010). The flood's features were processed for 180 floods, using CAVIS software from the NIHWM.

The meteorological data, the precipitation, the air temperature, the snow cover, were taken from the ECA&D database and the literature (Sandu et al., 2008), for the interval 1961 – 2000. The data belongs to the weather stations (WS) from the studied area or which are in the vicinity of the studied area. The potential evapotranspiration (ETP) was estimated for six weather stations by applying the Thornthwaite method (Fig. 1.B) (Data source: Baciu, 2008, ECA&D). The data regarding the snow cover was processed for only two weather stations due to lack of data (Data source: Geicu and Becheanu, 2008). The morphometrical data of the catchment and of the river network were obtained from topographic mapping. We processed, using GIS techniques with ArcGIS 9.3 software, the topographical map of Romania with a scale of 1:25000 (published in 1985).

3. GENERAL DATA REGARDING THE MAIN CAUSES OF THE FLOODS

Generally, the duration, the size and the shape of the floods are dependent on the physico – geographical characteristics of the catchment. Between these, the climatic conditions and the relief have an important role.

From a climatic point of view, the most important factors which influence the floods production are the precipitation, the air temperature and the snow cover. The average multiannual amounts of precipitation range from 504 mm (Roşiorii de Vede WS) and 939 mm (Ţarcu Peak WS) (ECA&D, Dragotă and Baciu, 2008), and the average multiannual air temperature between 10.2 °C (Caransebeş WS) and 11.7 °C (Drobeta Turnu Severin WS) (Săraru, 2008) (Fig. 1. B).



Weather station	Tmm	Pmm	Emm
Caransebeş	10.2	754	664
Craiova	11.2	567	711
Drobeta Turnu Severin	11.7	662	ND
Râmnicu Vâlcea	10.4	684	676
Roşiorii de Vede	10.7	504	703
Târgu Jiu	ND	765	677
Turnu Măgurele	11.3	520	740
Vârfu Ţarcu	ND	939	ND

Fig. 1. Jiu River Catchment – hydrographic network. A. Geographical position. B. Table with data on the average multiannual air temperature (Tmm) for 6 weather stations, the average multiannual precipitation (Pmm) for 8 weather stations, the average multiannual evapotranspiration (Emm). The meteorological data is for the interval 1961 – 2000. ND = no data.

The highest values of the maximum 24 hours, 48 hours and 72 hours precipitation amounts were recorded generally in summer, reaching a maximum in July due to the increase of the cyclonic activity (recorded at Craiova, Drobeta Turnu Severin and Târgu Jiu WS).

They determine the highest maximum monthly flows at the analyzed hydrometric stations. The lowest values of the maximum 24 hours, 48 hours and 72 hours precipitation amounts were recorded, generally, in winter, reaching a minimum in January.

The maximum 24 hours precipitation amounts mainly exceed the average multiannual precipitation in July, August, September and October, and the maximum 48 hours and 72 hours precipitation amounts exceed the average multiannual precipitation during all months. At Târgu Jiu WS, the average multiannual precipitation exceeds the maximum 48 hours precipitation amounts in December and in April and November at Craiova WS (Dragotă et al., 2008).

The average number of days with snow ranges from 24.8 days year^{-1} (Drobeta Turnu Severin WS) and 25.1 days year^{-1} (Târgu Jiu WS). The average duration of snow cover is 37.8 days year^{-1} at Drobeta Turnu Severin WS and 46.8 days year^{-1} at Târgu Jiu WS and the maximum duration is 86 days year^{-1} at Drobeta Turnu Severin WS and 95 days year^{-1} at Târgu Jiu WS. The average monthly thickness recorded, at both weather stations, has the highest value in January (between 6,5–7 cm) (Geicu, 2008).

From the morphometric point of view, the average altitude of the studied area is 445 m, and the maximum altitude is 2521 m (values obtained using GIS techniques) (Fig. 1). The high altitudes cause large amounts of precipitation and the low altitudes cause small amounts of precipitation. Consequently, the flow is richer at higher altitudes.

Analyzing the slope map of the studied area, it was discovered that 31% of the catchment area have slopes lower than 3° (3126 km²) and 69% (7005 km²) have slopes greater than 3°. The steeper slopes facilitate the high flow velocities, the intensity of the erosion process and of the sediments transport, the short concentration time of flash floods and so on.

4. FEATURES OF THE MAXIMUM FLOW

4.1. Variability of maximum monthly and annual discharge

The maximum flow is mainly due to the snowmelt and to the abundant rainfall. Its analysis is very important in the water resources management. The peak flows, for the interval 1982 – 2012, ranged from 34.2 m³ s^{-1} (Celei HS) and 1220 m³ s^{-1} (Zăval HS) and the average maximum annual discharge ranged from 17.4 m³ s^{-1} (Celei HS) and 637 m³ s^{-1} (Răcari HS).

The average maximum annual discharge was exceeded in 29% of cases (Corcova HS) and 50% of cases (Răcari HS) (Table 1). The linear trend of the maximum annual discharge is generally to increase and it is statistically significant only in the case of Zăval HS (with a level of significance of 0.1) and Teleşti HS (with a level of significance of 0.001).

A decreasing trend was identified for Rovinari HS and Turceni HS, statistically insignificant, according to the statistical Mann – Kendall test.

Table 1. Morphometric and hydrologic features of the studied rivers

No	River	Hydrometric station	F (km²)	H (m)	L (km)	Q_{max} ($m^3 s^{-1}$)	Q_{maxmed} ($m^3 s^{-1}$)	Over Q_{maxmed} (%)	C_v
1	Jiul de Vest	Iscroni	496	**1134**	54	226	111	48	0.50
2	Jiu	Sadu	1269	1066	88	394	169	44	0.48
3	Jiu	Rovinari	2910	697	126	549	315	39	0.35
4	Jiu	Filiaşi	5304	563	194	889	516	48	0.38
5	Jiu	Răcari	7325	508	201	1036	**637**	**50**	0.40
6	Jiu	Podari	9334	446	255	1170	626	47	0.43
7	Jiu	Zăval	**10073**	417	**323**	**1220**	631	48	0.42
8	Orlea	Celei	*62*	538	*12.6*	*34.2*	*17.4*	42	0.51
9	Jaleş	Runcu	118	976	19.8	141	36.5	38	0.79
10	Jaleş	Stolojani	154	851	28.3	141	44.1	35	0.79
11	Bistriţa	Teleşti	270	540	35.6	375	73.9	35	0.92
12	Jilţ	Turceni	375	247	49	121	47.3	48	0.67
13	Gilort	Turburea	1078	590	87	436	178	42	0.65
14	Motru	Târmigani	304	751	32.5	308	86.6	34	0.78
15	Motru	Broşteni	646	526	66	548	138	42	0.68
16	Coşuştea	Corcova	420	482	73	421	70.9	*29*	1.04
17	Huşniţa	Strehaia	310	257	43.1	154	31.2	39	0.92
18	Raznic	Breasta	465	*201*	39.4	218	47.2	41	1.09

F = catchment area (corresponding to the hydrometric station); H = average altitude of the catchment area (at the level of the hydrometric station); L = the length of the stream (spring – hydrometric station), Q_{max} = the peak flow, Q_{maxmed} = the average maximum multiannual discharge, C_v = the variation coefficient, *italic* = minimum values, **bold** = maximum values. Source data: NIHWM.

4.2. Maximum discharge with different exceeding probabilities

The study on the maximum discharges with different exceeding probabilities is necessary to build hydraulic structures and flood defense structures. The variation coefficient is approximately equal to 1 ($C_v = 1$) and for the symmetry coefficient was chosen the calculated value ($C_s = 4C_v$) (Diaconu and Lăzărescu, 1965). The peak flows recorded at the studied hydrometric stations, generally, exceeded the estimated values of the maximum discharge with the probability of 1% (Broşteni, Teleşti and Corcova HS), 3% (Sadu, Runcu, Stolojani, Târmigani, Strehaia and Breasta HS), 5% (Iscroni, Rovinari, Podari, Zăval, Turburea and Turceni HS) and 10% (Filiaşi, Răcari and Celei HS) (Table 2).

Table 2. Maximum discharges ($m^3 s^{-1}$) with different exceeding probabilities (p%)

No.	River	Hydrometric station	0.1%	1%	3%	5%	10%
1	Jiul de Vest	Iscroni	429	306	247	**220**	182
2	Jiu	Sadu	631	453	**368**	329	274
3	Jiu	Rovinari	855	663	568	**524**	459
4	Jiu	Filiasi	1536	1159	978	895	**773**
5	Jiu	Răcari	1946	1466	1234	1128	**974**
6	Jiu	Podari	2029	1514	1262	**1146**	980
7	Jiu	Zăval	2046	1520	1264	**1145**	976
8	Jales	Runcu	242	155	**113**	93.6	68.8
9	Jaleş	Stolojani	291	184	**134**	111	82
10	Bistrita	Telesti	596	**365**	261	211	151
11	Orlea	Celei	69.3	48.9	39.3	34.9	**28.8**
12	Motru	Târmigani	570	361	**264**	219	162
13	Motru	Brosteni	751	**496**	375	321	247
14	Cosustea	Corcova	675	**389**	270	208	140
15	Husnita	Strehaia	257	155	**110**	87.4	61.7
16	Gilort	Turburea	925	618	475	**408**	318
17	Jilt	Turceni	263	172	129	**110**	84.3
18	Raznic	Breasta	471	271	**188**	144	96

The hydrological data was processed for the interval 1982 – 2012. The results were obtained using ASIG software (NIHWM).

5. FEATURES OF THE FLOODS

5.1. Frequency of the floods

The annual floods have a maximum frequency in April, for 38% of total studied cases, followed by December, for 28% of cases. The minimum frequency of annual floods is specific for January (for 19% of cases), followed by August, 14% of cases. In the studied period, the annual floods weren't recorded in the next months: January (Iscroni, Sadu, Rovinari and Runcu HS), February (Iscroni, Sadu, Runcu and Stolojani HS), May (Celei HS), July (Runcu HS), August (Rovinari, Filiaşi, Răcari, Celei, Stolojani, Târmigani, Broşteni and Corcova HS), September (Filiaşi, Răcari, Podari, Zăval, Turburea, Târmigani, Broşteni, Corcova and Strehaia HS), October (Filiaşi, Răcari, Podari, Zăval, Turceni, Broşteni, Corcova, Strehaia and Breasta HS) (Fig. 2).

At a seasonal scale, the minimum number of annual floods is recorded during autumn (available for 74% of the studied cases) and the maximum number of annual floods during spring (available for 60% of the studied cases), followed by winter, for 30% of cases (Fig. 2).

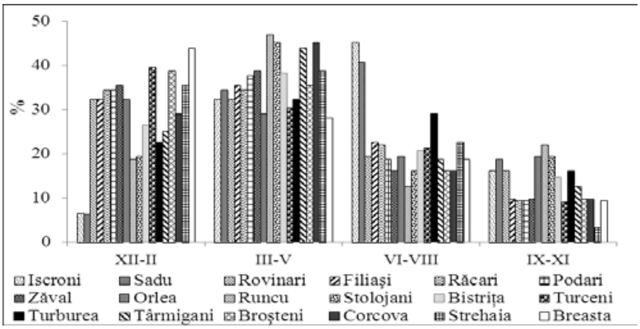


Fig. 2. Seasonal frequency of the annual floods at studied hydrometric station

For a more rigorous analysis of the floods' potential in the Jiu River catchment we determined the number of cases in which the flow thresholds were exceeded by the analyzed peak flows. The alert thresholds are used in the operational activity from the NIHWM, for the delimitation of the areas which are affected by the floods and/or flooding and are established according to physico – geographical features of the catchment, the position of the socio – economical objectives and to the infrastructure.

The floods with peak flows higher than the alert thresholds have a maximum frequency in April and November (16% of cases). There weren't floods with peak flows higher than the flooding discharge at Sadu, Rovinari, Teleşti and Zăval HS and floods with peak flows higher than the danger discharge at Sadu, Rovinari, Podari, Zăval, Runcu, Stolojani, Turceni, Turburea, Strehaia and Celei HS. The flooding threshold has often been exceeded at the Celei HS (10 times in 31 cases), Corcova HS (11 times in 23 cases) and Răcari HS (12 times in 29 cases), and the danger threshold at Răcari HS (5 times in 29 cases) and Târmigani HS (3 times of 17 cases) (according to the alert thresholds used in NIHWM, 2013).

At an annual scale, the highest number of cases in which the discharge thresholds were exceeded by the peak flows of the floods was recorded in 1999 and 2007, for 19% of cases.

5.2. Characteristics of the floods

The analysis regarding the characteristics of floods (the increasing time, the decreasing time, the total duration, the peak flow, the flood volume, the form factor and so on) highlights their manifestation. This study is necessary and important, on the one hand, for the hydrological forecasting and the floods' risk assessment and, on the other hand, in order to build the hydraulic structures.

To analyze the flood's characteristics, we studied 10 floods for each analyzed hydrometric station, which corresponded to the major events that occurred. Overall, the average total duration in the Jiu River Catchment varies between 38 hours (Turburea HS) and 228 hours (Zăval HS), the average increasing time ranges between 12 hours (Strehaia HS) and 78 hours (Zăval HS) and the average decreasing time between 21 hours (Turburea HS) and 153 hours (Podari HS) (Table 3). Generally, the total time and the increasing time have higher values when the catchment area and the river length have higher values and have lower values when the slopes of the river and of the catchment are steeper (Diaconu, 1965).

Table 3. The mean values of the flood events

No.	River	Hydrometric station	T_t (hours)	T_c (hours)	T_d (hours)	W_t (mil.m³)	γ
1	Jiul de Vest	Iscroni	88	14	74	26.1	0.3
2	Jiu	Sadu	111	24	87	40.1	0.4
3	Jiu	Rovinari	65	24	41	69.7	0.7
4	Jiu	Filiaşi	145	50	95	263.3	0.6
5	Jiu	Răcari	101	40	61	212.2	0.7
6	Jiu	Podari	220	67	**153**	455.0	0.5
7	Jiu	Zăval	**228**	**78**	151	427.6	0.5
8	Bistriţa	Teleşti	84	18	66	15.8	0.4
9	Jilţ	Turceni	66	21	45	7.9	0.4
10	Gilort	Turburea	*38*	17	*21*	26.4	0.5
11	Motru	Târmigani	73	19	54	28.1	0.4
12	Motru	Broşteni	84	29	55	38.4	0.3
13	Coşuştea	Corcova	74	19	54	23.3	0.4
14	Huşniţa	Strehaia	43	*12*	31	5.7	0.4
15	Raznic	Breasta	70	26	44	16.3	0.4
16	Orlea	Celei	74	21	53	3.7	0.5
17	Jaleş	Runcu	96	16	79	9.3	0.4
18	Jaleş	Stolojani	111	28	82	16.5	0.4

T_t = the total duration; T_c = the increasing time; T_d = the decreasing time; W_t = the total volume; γ = the form factor, *italic* = minimum values, **bold** = maximum values.

6. CONCLUSIONS

The Jiu River Catchment represents, due to the physico – geographical conditions, an area which is frequently affected by floods and floodings. The analyzed floods have an average increasing time which ranges from 12 hours (Strehaia HS) to 78 hours (Zăval HS), and occur frequently in the spring (over 32% of cases). The peak flows recorded at the analyzed hydrometric stations exceeded the estimated values for the maximum discharges with the probability of 1%, 3%, 5% and 10%. Knowing the features of the maximum flow and the floods in the studied area, protective measures need to be developed against the risk induced by the floods.

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